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Matsumura et al.

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(54) **RFID TAG**

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(30) **Foreign Application Priority Data**

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G06K 19/00 (2006.01)
G06K 19/077 (2006.01)
G06K 19/02 (2006.01)

(52) **U.S. Cl.**
CPC ***G06K 19/07749*** (2013.01); ***G06K 19/025*** (2013.01)

(58) **Field of Classification Search**
USPC 235/492
See application file for complete search history.

(56) **References Cited**

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(57) **ABSTRACT**

There is provided an RFID tag which includes a first sheet portion including a first projection-depression portion formed in a longitudinal direction or a first groove portion formed in a direction forming an angle with the longitudinal direction, an antenna formed on a surface of the first sheet portion, the antenna being flexible and elastic, an integrated circuit chip electrically connected to the antenna, a second sheet portion including a second projection-depression portion formed in the longitudinal direction or a second groove portion formed in a direction forming an angle with the longitudinal direction, the antenna and the integrated circuit chip being covered between the first sheet portion and the second sheet portion, and a package member covering the first sheet portion and the second sheet portion, the package member being flexible and elastic.

9 Claims, 14 Drawing Sheets

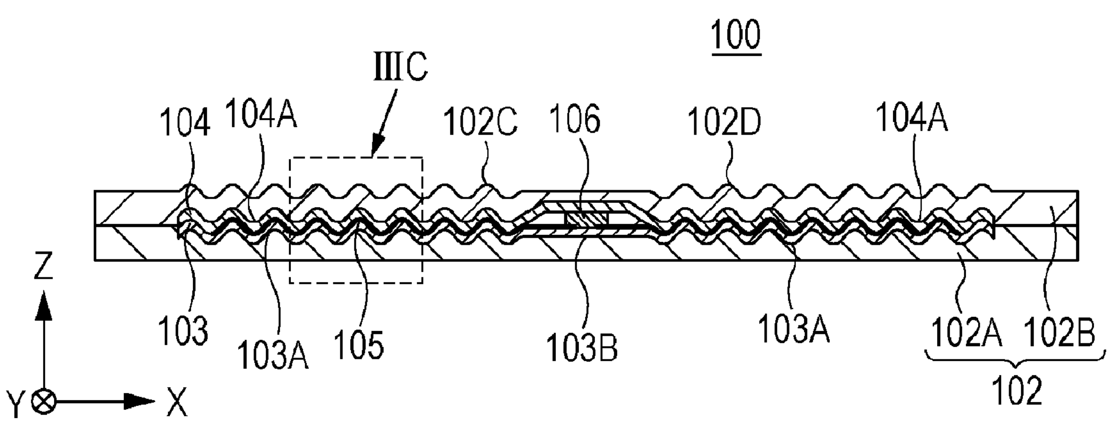


FIG. 1A
RELATED ART

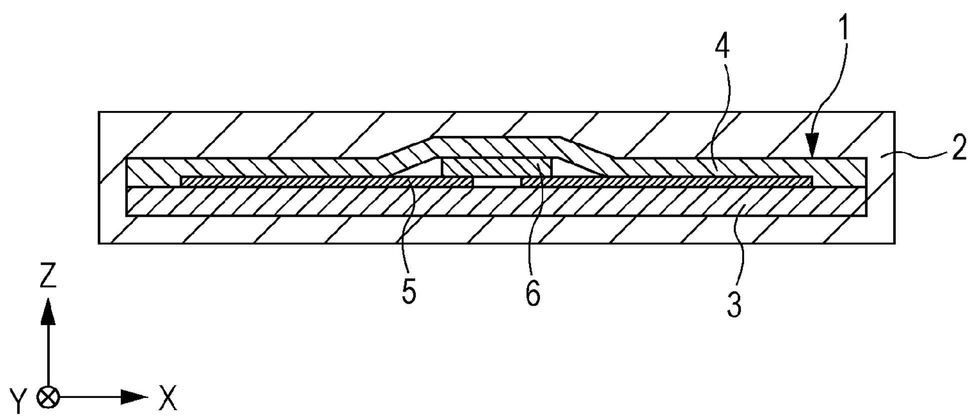
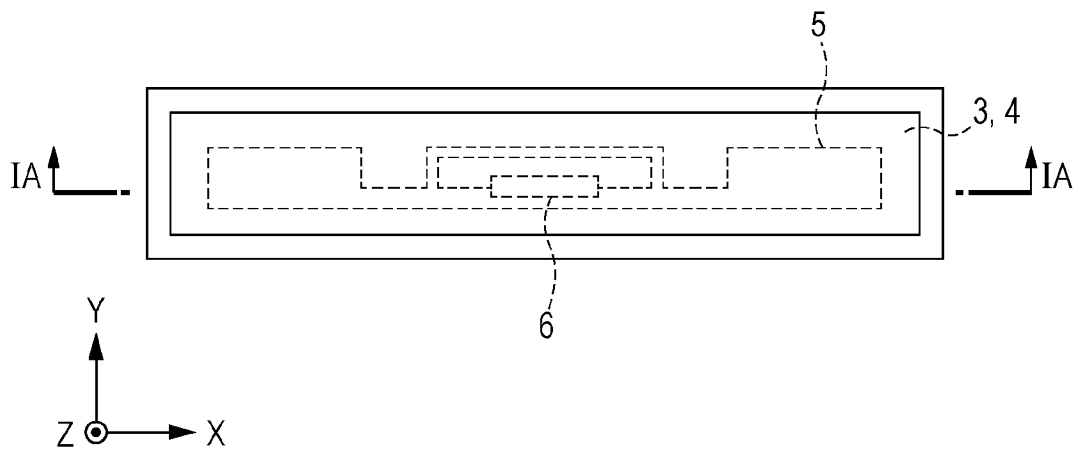


FIG. 1B
RELATED ART



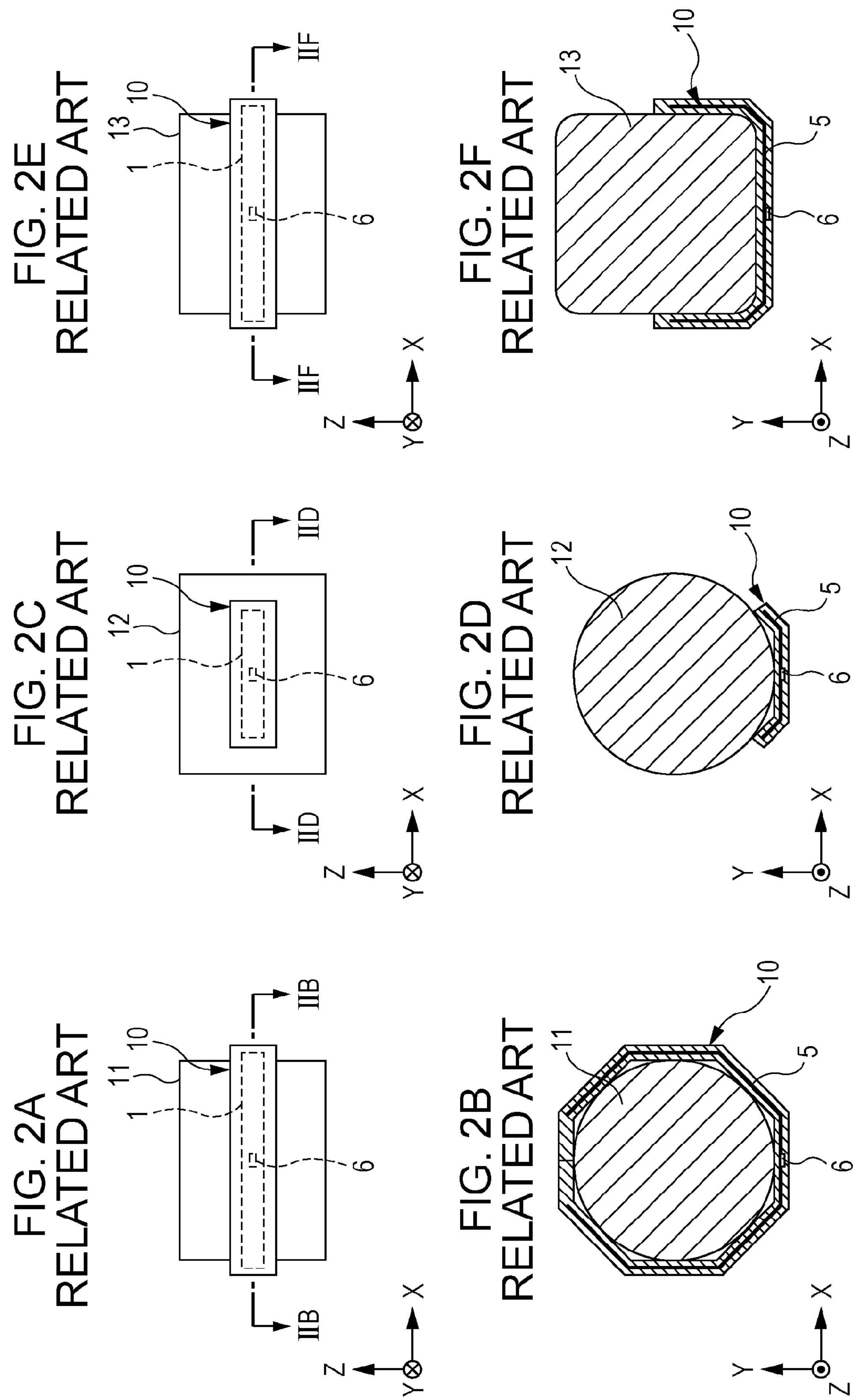


FIG. 2A RELATED ART

FIG. 2B RELATED ART

FIG. 2C RELATED ART

FIG. 2D RELATED ART

FIG. 2E RELATED ART

FIG. 2F RELATED ART

FIG. 3A

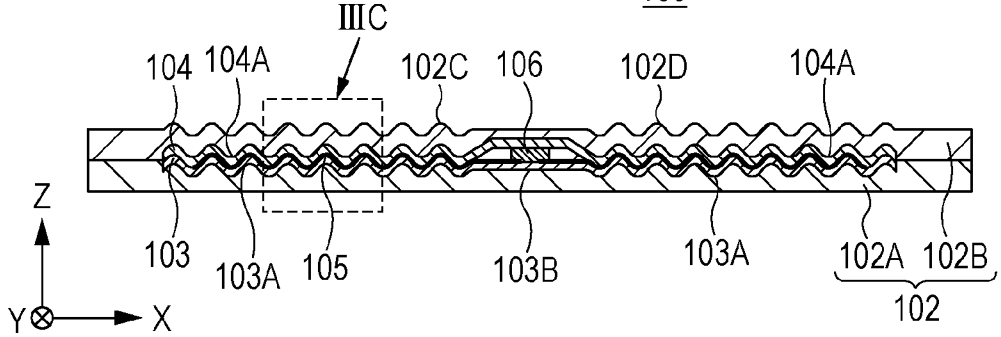


FIG. 3B

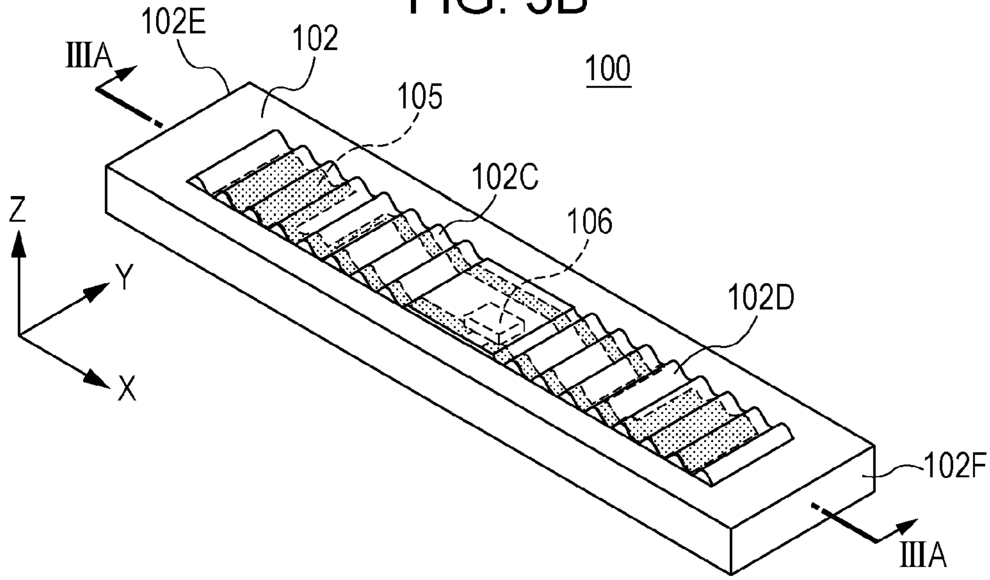
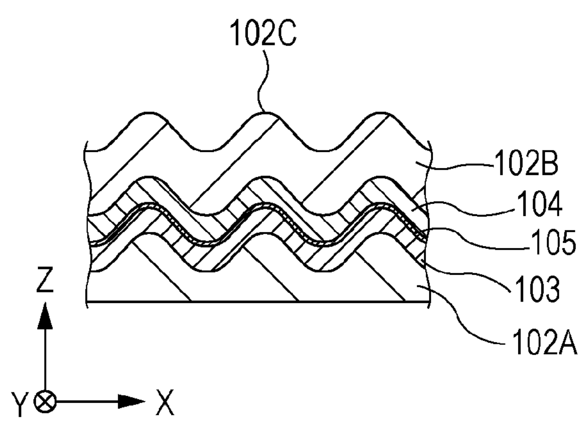


FIG. 3C



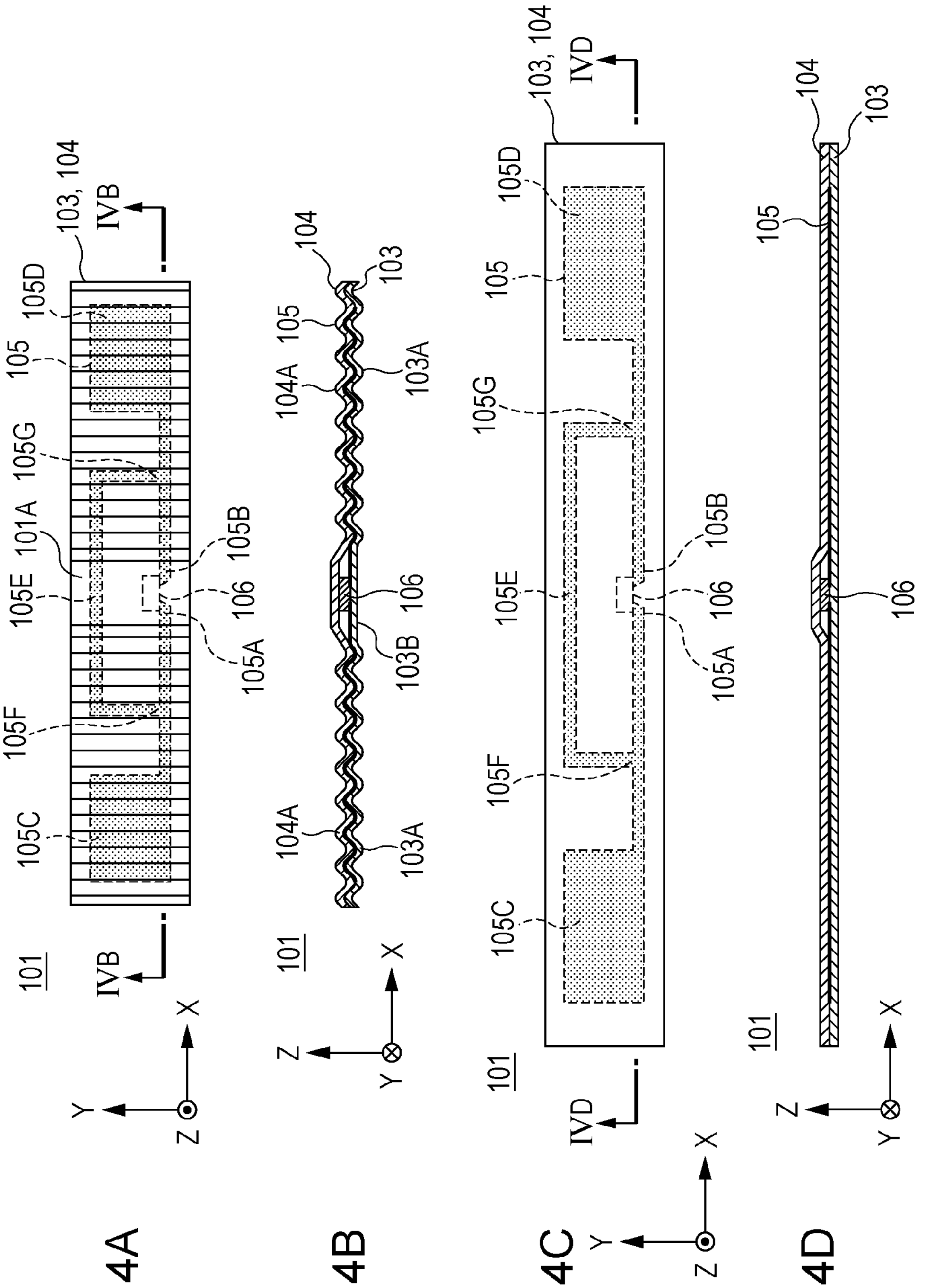


FIG. 4A

FIG. 4B

FIG. 4C

FIG. 4D

FIG. 5A

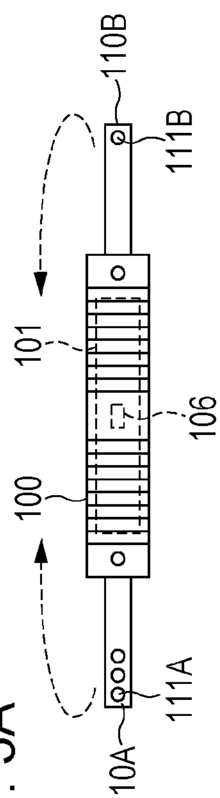


FIG. 5B

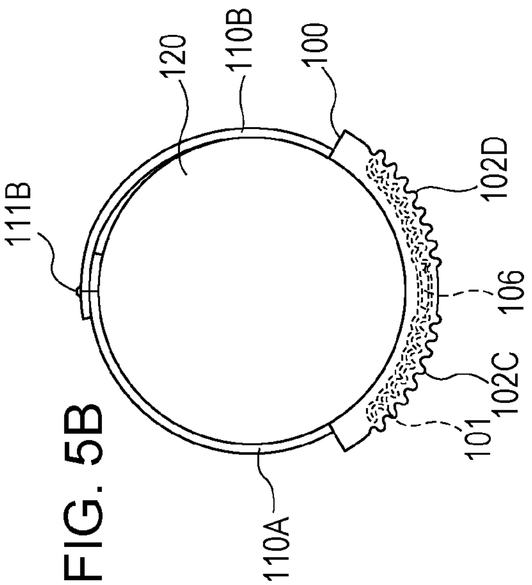


FIG. 5C

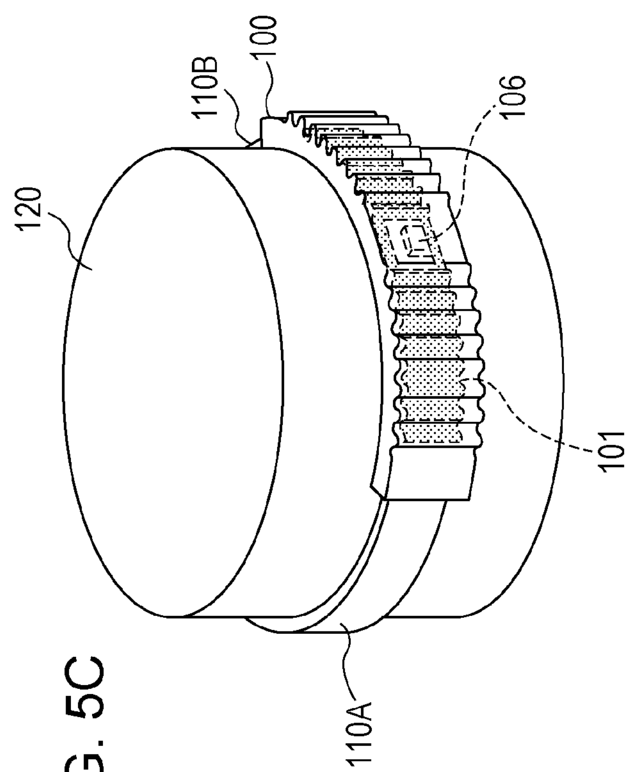


FIG. 5D

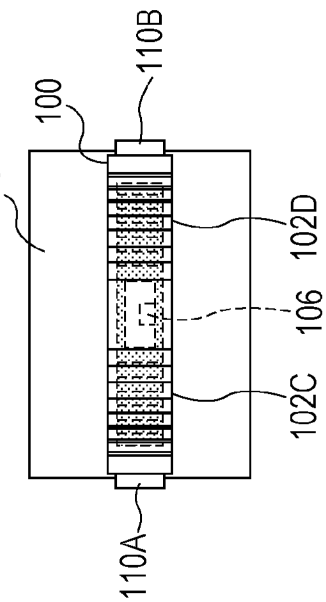


FIG. 6B

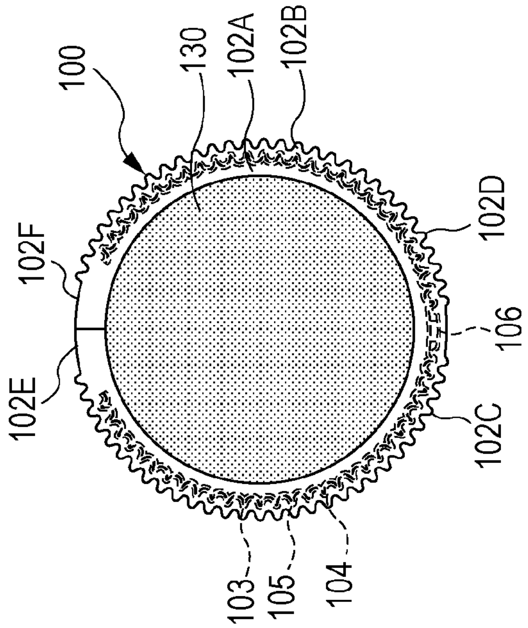


FIG. 6C

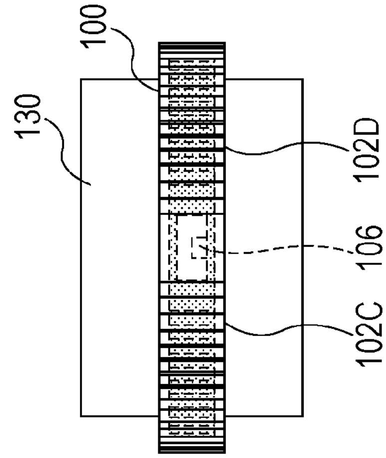
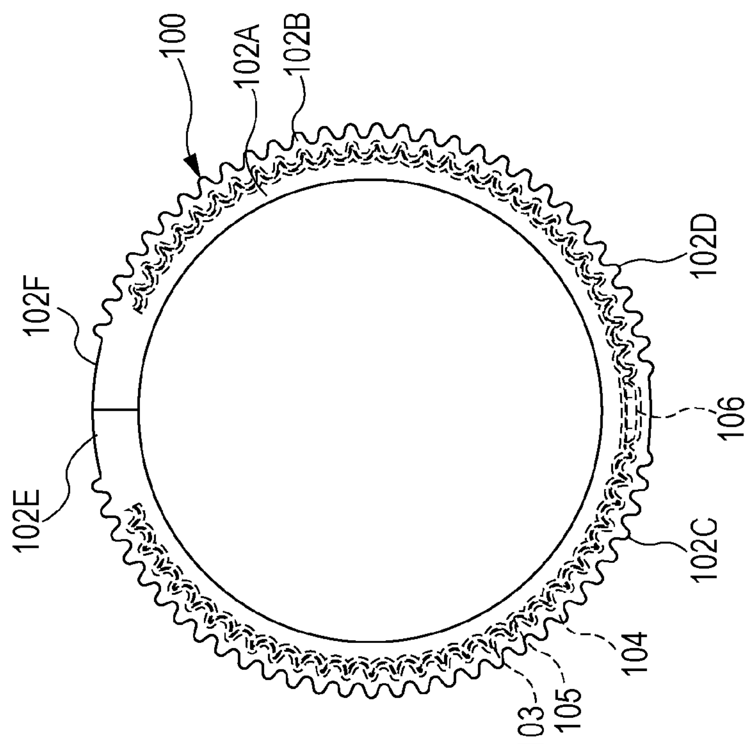


FIG. 6A



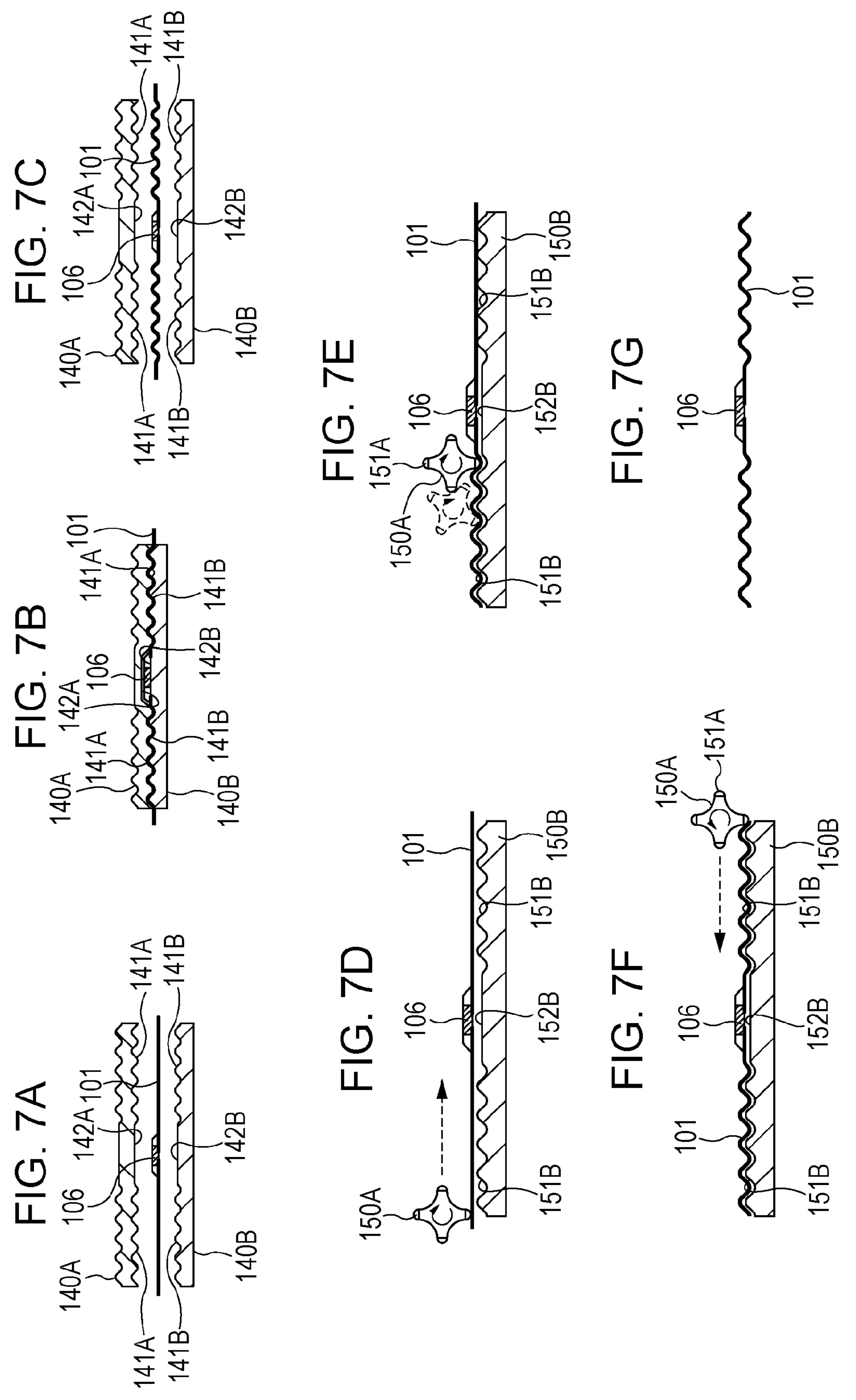


FIG. 7A

FIG. 7B

FIG. 7C

FIG. 7D

FIG. 7E

FIG. 7F

FIG. 7G

FIG. 8

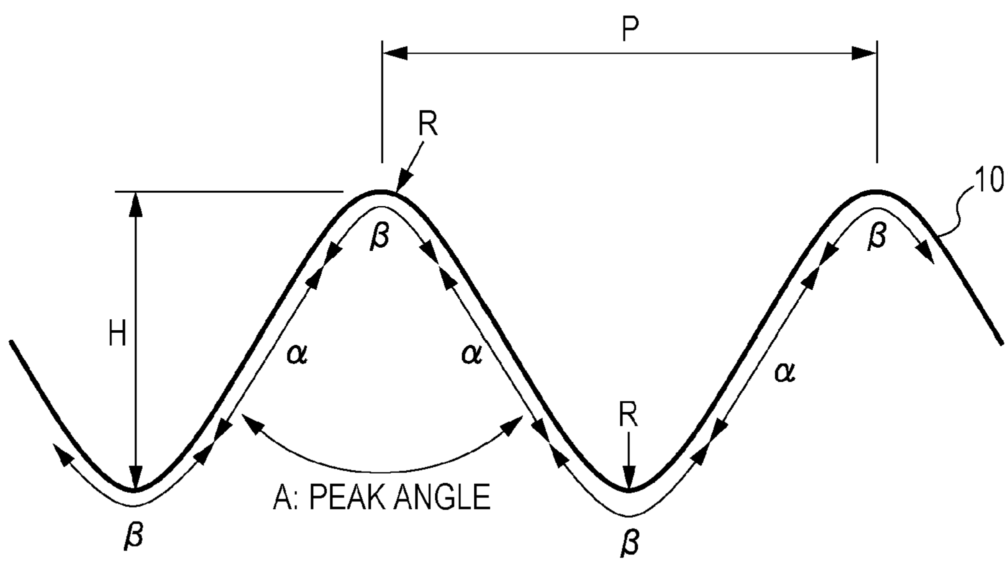


FIG. 9A

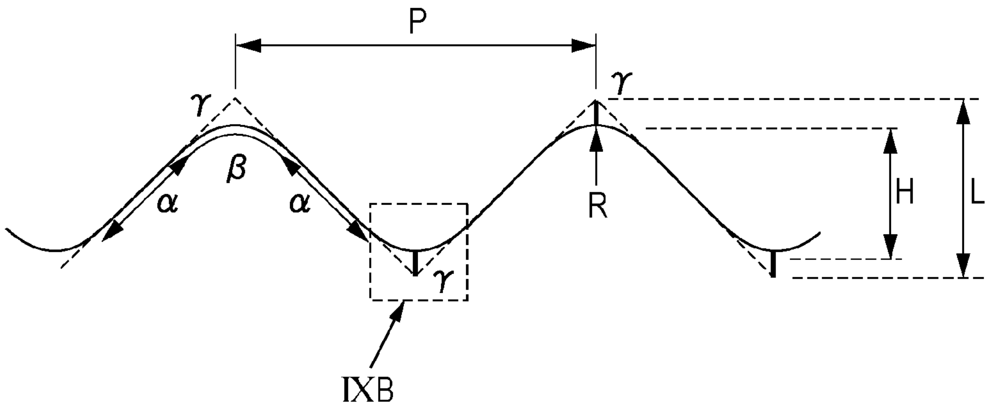


FIG. 9B

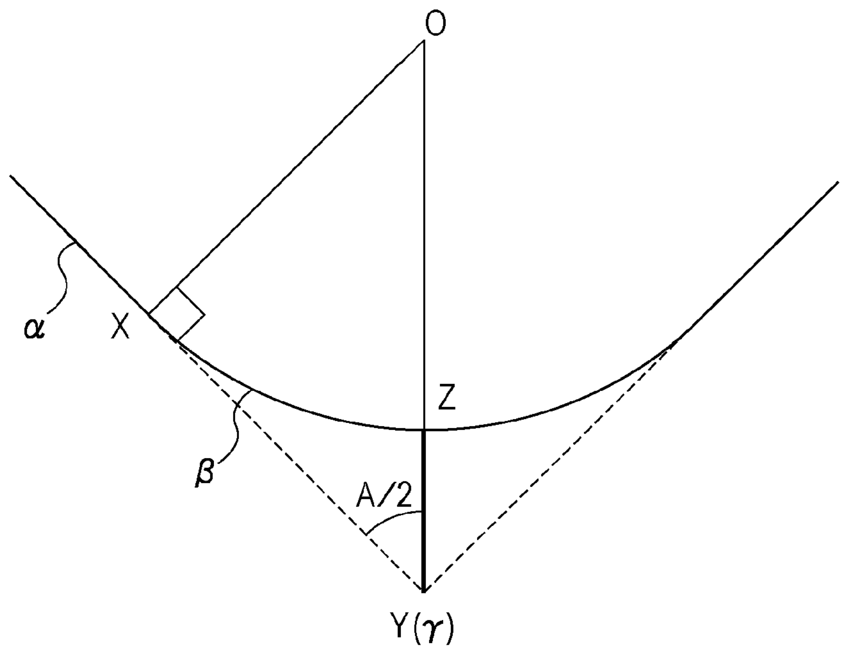


FIG. 10A

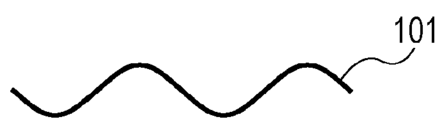


FIG. 10B

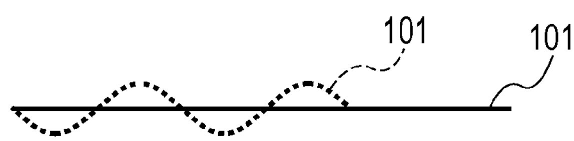


FIG. 11A

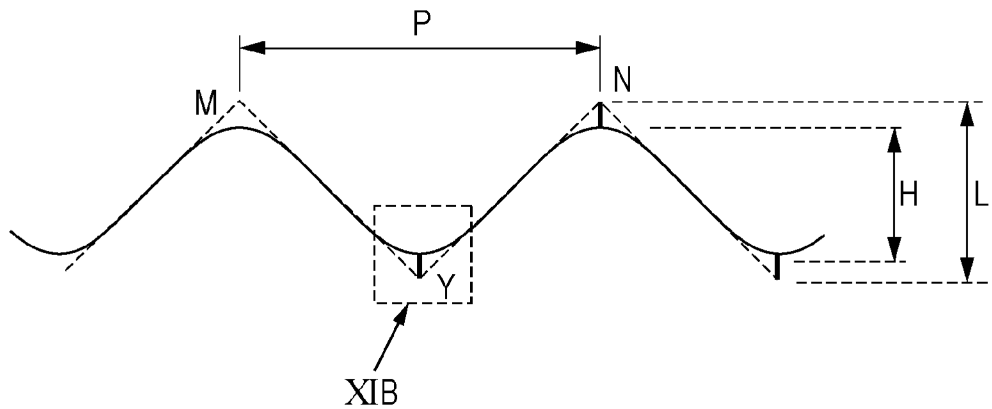


FIG. 11B

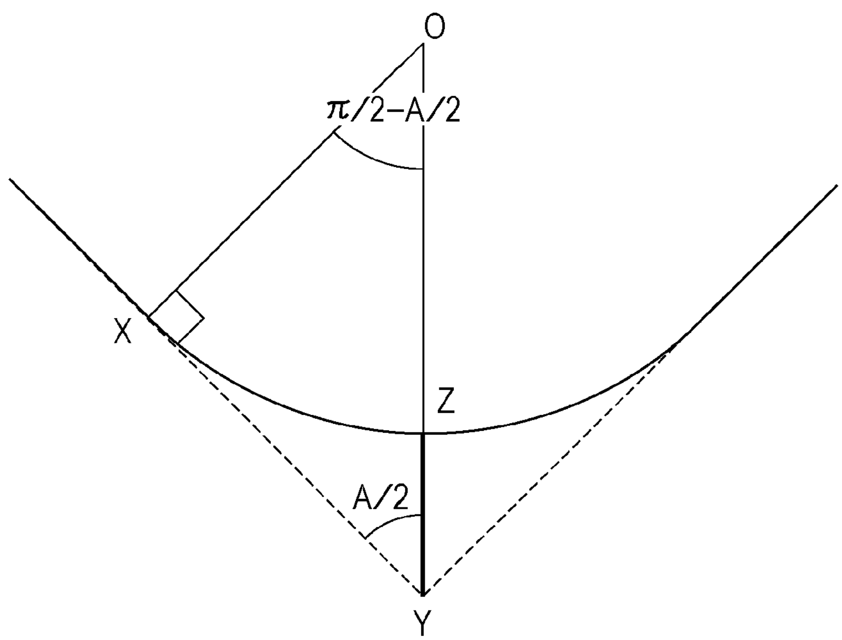


FIG. 12A

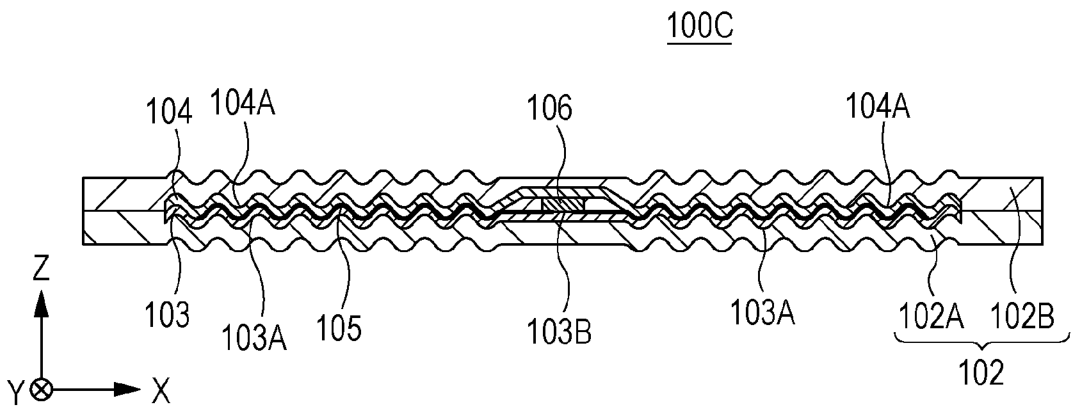


FIG. 12B

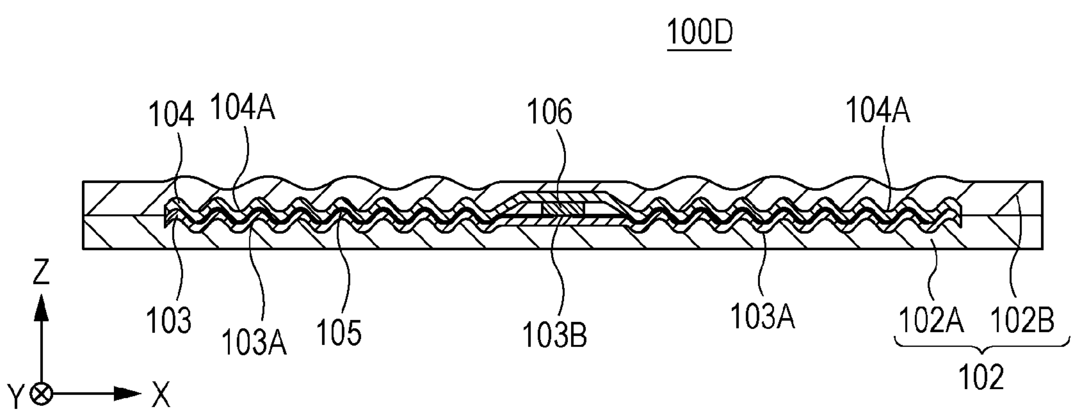


FIG. 13A

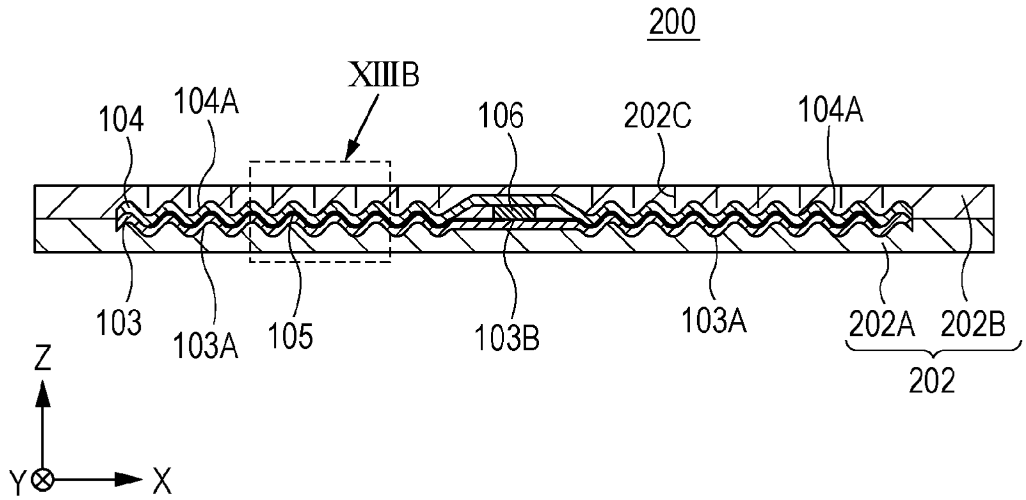


FIG. 13B

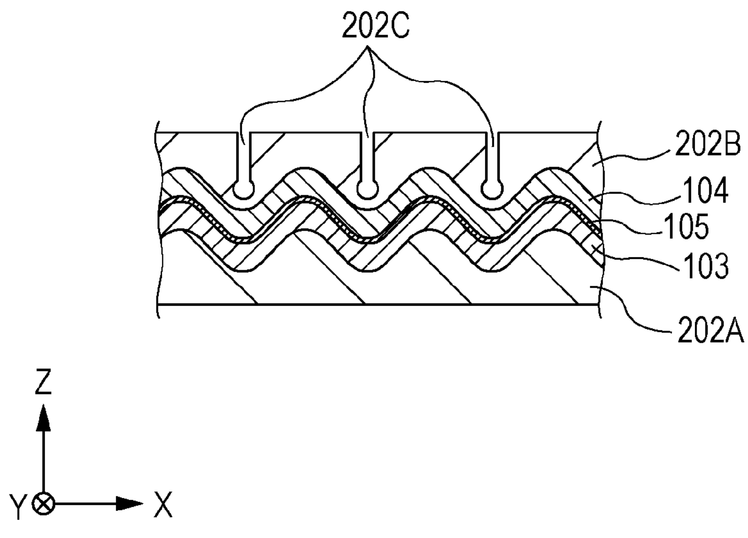


FIG. 14A

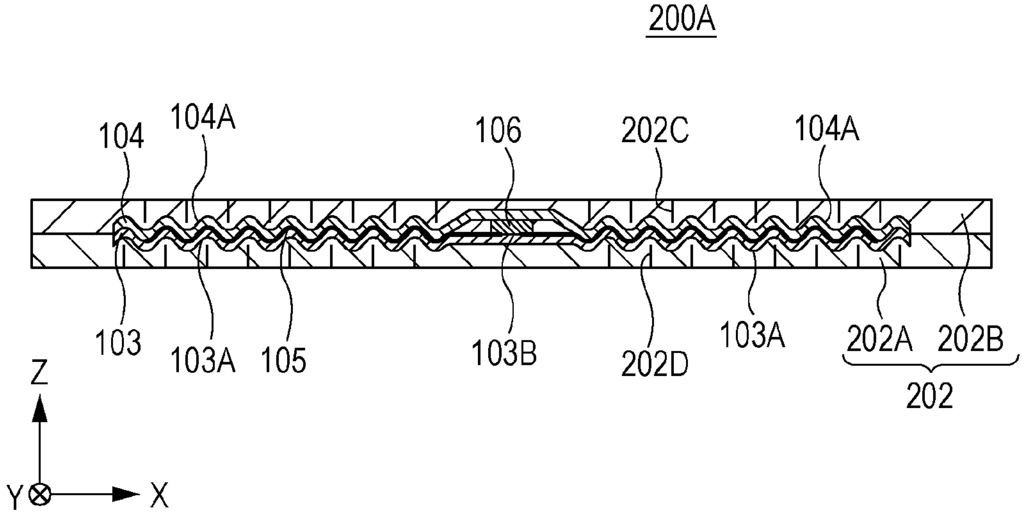
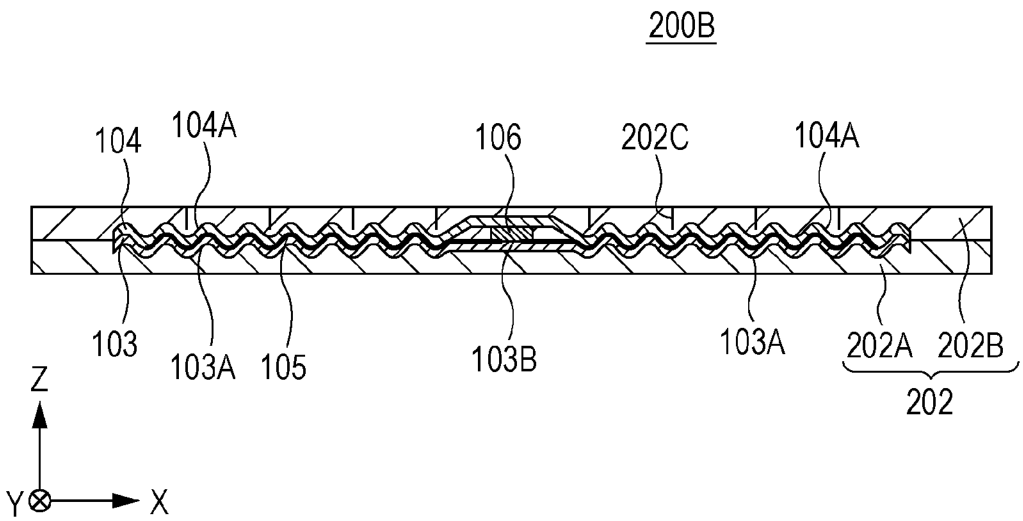


FIG. 14B



RFID TAG

CROSS-REFERENCE TO RELATED APPLICATION

This application is based upon and claims the benefit of priority of the prior Japanese Patent Application No. 2012-174239 filed on Aug. 6, 2012, the entire contents of which are incorporated herein by reference.

FIELD

The embodiments discussed herein are related to an RFID tag.

BACKGROUND

There are non-contact type ID cards, such as RFID cards, in which an antenna coil is disposed in the card main body. In such an ID card, the antenna coil has a wave shape in which multiple projections and depressions are formed in a thickness direction of the card main body (for example, see Japanese Laid-open Patent Publication No. 08-034185).

SUMMARY

According to an aspect of the invention, an RFID tag includes a first sheet portion including a first projection-depression portion formed in a longitudinal direction or a first groove portion formed in a direction forming an angle with the longitudinal direction, an antenna formed on a surface of the first sheet portion, the antenna being flexible and elastic, an integrated circuit chip electrically connected to the antenna, a second sheet portion including a second projection-depression portion formed in the longitudinal direction or a second groove portion formed in a direction forming an angle with the longitudinal direction, the antenna and the integrated circuit chip being covered between the first sheet portion and the second sheet portion, and a package member covering the first sheet portion and the second sheet portion, the package member being flexible and elastic.

The object and advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the claims.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF DRAWINGS

FIGS. **1**A and **1**B are views illustrating an RFID tag of a comparative example;

FIGS. **2**A to **2**F are views illustrating states in which the RFID tag of the comparative example is affixed to a curved surface of an article;

FIGS. **3**A to **3**C are views illustrating an RFID tag according to a first embodiment;

FIGS. **4**A to **4**D are views illustrating an inlet of the RFID tag according to the first embodiment;

FIGS. **5**A to **5**D are views illustrating a fastened state of the RFID tag according to the first embodiment;

FIGS. **6**A to **6**C are views illustrating another fastened state of the RFID tag according to the first embodiment;

FIGS. **7**A to **7**G are views illustrating processing steps subjected to the inlet of the RFID tag according to the first embodiment;

FIG. **8** is an explanatory view of a wave shape of the RFID tag according to the first embodiment;

FIGS. **9**A and **9**B are explanatory views of the wave shape of the RFID tag according to the first embodiment;

FIGS. **10**A and **10**B are views illustrating expansion and shrinkage of the inlet;

FIGS. **11**A and **11**B are explanatory views of a method of determining an expansion and shrinkage rate of the inlet;

FIGS. **12**A and **12**B are views illustrating RFID tags according to modifications of the first embodiment;

FIGS. **13**A and **13**B are views illustrating an RFID tag according to a second embodiment; and

FIGS. **14**A and **14**B are views illustrating RFID tags according to modifications of the second embodiment.

DESCRIPTION OF EMBODIMENTS

Unfortunately, there are cases where an ID card, as described in the background, is damaged when being affixed to a curved surface, in particular, an elastic curved surface. Thus, ID cards of this type are prone to being non-durable.

Therefore, a highly durable RFID tag is needed.

Hereinafter, a description will be given of a radio frequency identification (RFID) tag according to embodiments.

Before RFID tags of the embodiments are described, a disadvantage of an RFID tag of a comparative example will be described below.

Comparative Example

FIGS. **1**A and **1**B are views illustrating an RFID tag **10** of a comparative example; FIG. **1**A is a cross section of the RFID tag **10**, and FIG. **1**B is a plan view of the RFID tag **10** given in a transparent manner. In more detail, FIG. **1**A is a view illustrating the cross section taken along an arrow IA-IA of FIG. **1**B. In FIGS. **1**A and **1**B, the dimensions of the RFID tag **10** are defined by an orthogonal coordinate system, more specifically, an XYZ coordinate system as illustrated in FIGS. **1**A and **1**B.

Hereinafter, in the drawings, a surface facing upward is defined as an "upper surface," and a surface facing downward is defined as a "lower surface." However, this definition is given so as to facilitate understanding the following explanation, and is not necessarily applicable to any given surfaces.

The RFID tag **10** of the comparative example includes an inlet **1** and a package **2**. In more detail, the inlet **1** includes sheets **3** and **4**, an antenna **5**, and an IC chip **6**, and the package **2** is made of rubber and covers the inlet **1**.

Note that in FIG. **1**B, the upper surface of the RFID tag **10** in FIG. **1**A is illustrated in a transparent manner, and the upper half part of the package **2** and the sheet **4** are omitted.

Each of the sheets **3** and **4** is a polyethylene terephthalate (PET) film. The antenna **5** is used for communication, and is arranged on the upper surface of the sheet **3**. The IC chip **6** is mounted on the upper surface of the sheet **3** and is electrically connected to the antenna **5**, thereby enabling wireless communication to be conducted through the antenna **5**. The sheet **4** is bonded to the upper surface of the sheet **3**, thereby covering the antenna **5** and the IC chip **6** together with the sheet **3**.

The package **2** is formed by bonding upper and lower separate pieces with thermal fusion processing, so that the package **2** covers the inlet **1**.

Then, a description will be given of a disadvantage arising when the RFID tag **10** of the comparative example, as described above, is affixed to the curved surface of an article, with reference to FIGS. **2**A to **2**F.

FIGS. **2**A to **2**F are views illustrating states in which the RFID tag **10** of the comparative example is affixed to the curved surface of an article. In FIG. **2**A, the RFID tag **10** is affixed to the side surface of a cylindrical member **11** so as to encircle the side surface.

FIG. **2**B is a cross-section view taken along an arrow IIB-IIB of FIG. **2**A. When the RFID tag **10** is affixed to the curved surface of the cylindrical member **11** having a great curvature, as illustrated in FIG. **2**B, the PET sheets **3** and **4** may fail to be bent along the curved surface and be broken. As a result, the inlet **1** would be damaged. In addition, the connecting portion of the antenna **5** and the IC chip **6** may also be damaged, so that the RFID tag **10** would be unable to operate.

FIG. **2**C is a view illustrating a state where the RFID tag **10** is affixed to part of the side surface of a cylindrical member **12**. FIG. **2**E is a view illustrating a state where the RFID tag **10** is affixed to part of the side surface of a square-prism-shaped member **13**. The square-prism-shaped member **13** is rounded at the four corners thereof.

FIGS. **2**D and **2**F are cross-section views taken along arrows IID-IID and IIF-IIF of FIGS. **2**C and **2**E, respectively. When the RFID tag **10** is affixed to the curved surface, as illustrated in FIG. **2**D or **2**F, the PET sheets **3** and **4** may fail to be bent along the curved surface and be broken. As a result, the inlet **1** would be damaged. In addition, the connecting portion of the antenna **5** and the IC chip **6** may also be damaged, so that the RFID tag **10** would be unable to operate.

As described above, the RFID tag **10** of the comparative example may be damaged when being affixed to the curved surface of an article.

Even if the RFID tag **10** of the comparative example is not damaged upon being affixed to the curved surface of an article, when the article is deformed due to thermal expansion or shrinkage, there are cases where the RFID tag **10** fails to absorb this deformation and is damaged.

Thus, the RFID tag **10** of the comparative example has a disadvantage in terms of durability.

Therefore, the embodiments that will be described below aim to provide a highly durable RFID tag.

First Embodiment

FIGS. **3**A to **3**C are views illustrating an RFID tag **100** according to a first embodiment. Specifically, FIG. **3**A is a cross-section view of the whole of the RFID tag **100**; FIG. **3**B is a perspective view of the RFID tag **100**; and FIG. **3**C is an enlarged view of part surrounded by a dotted line IIIC of FIG. **3**A. FIG. **3**A is a cross-section view taken along an arrow IIIA-IIIA of FIG. **3**B. In FIGS. **3**A to **3**C, the dimensions of RFID tag **100** are defined by an orthogonal coordinate system, more specifically, an XYZ coordinate system.

The RFID tag **100** according to the first embodiment includes an inlet **101** and a package **102**. The inlet **101** includes sheets **103** and **104**, an antenna **105**, and an IC chip **106**. In the RFID tag **100**, the lower surface of the package **102** is to be affixed to an article.

The inlet **101** is processed into a wave shape in a longitudinal direction thereof (or in an X-axial direction in FIGS. **3**A to **3**C), except for a middle portion in the longitudinal direction on which the IC chip **106** is mounted. The portion processed into a wave shape in the longitudinal direction is an example of a projection-depression portion formed in the longitudinal direction. In order to process the inlet **101** into a wave shape in this manner, thermal processing is used. Note that a method of forming the inlet **101** will be described later.

Each of the sheets **103** and **104** is a polyethylene terephthalate (PET) film processed into a wave shape in a longitudinal direction thereof (or in the X-axial direction in FIGS. **3**A to **3**C). Note that although the sheets **103** and **104** are omitted from the perspective view of FIG. **3**B for better viewability, wave portions **102**C and **102**D on the upper surface of the package **102** correspond to the wave portions of the sheets **103** and **104**. The wave portions **102**C and **102**D are an example of a third projection-depression portion.

The sheet **103** is an example of a first sheet portion, and the sheet **104** is an example of a second sheet portion. Wave-shaped processed portions **103**A on the sheet **103** are an example of a first projection-depression portion formed in the longitudinal direction. Wave-shaped processed portions **104**A on the sheet **104** are an example of a second projection-depression portion formed in the longitudinal direction.

The wave-shaped processed portions **103**A and **103**A on the sheet **103** have the same wave phase as the wave-shaped processed portions **104**A and **104**A on the sheet **104** does. In other words, the wave phase of the wave-shaped processed portions **103**A and **103**A on the sheet **103** corresponds to that of the wave-shaped processed portions **104**A and **104**A on the sheet **104**.

The sheet **103** includes the two wave-shaped processed portions **103**A and **103**A, and a flat portion **103**B provided therebetween.

The antenna **105** and the IC chip **106** are mounted on the upper surface of the sheet **103**. The IC chip **106** is mounted on the flat portion **103**B. The wave shapes of the sheets **103** and **104** are processed by: for example, mounting the antenna **105** and the IC chip **106** on the upper surface of the flat sheet **103**; bonding the sheet **104** to the upper surface of the flat sheet **103** so as to cover the antenna **105** and the IC chip **106**, thereby forming the flat inlet **101**; and subjecting the flat inlet **101** to thermal processing. Note that the sheets **103** and **104** may be bonded to each other with, for example, an acrylic adhesive tape.

Each of the sheets **103** and **104** may also be any other film instead of a PET film, such as a polypropylene film or a vinyl chloride film.

The antenna **105** is formed on one surface (or the upper surface) of the sheet **103**, and may be made of, for example, a silver paste. The silver paste may be produced by mixing a thermosetting resin and a silver powder. The silver paste is applied to the surface of the sheet **103**, and is cured by means of heat, so that the antenna **105** is formed.

Note that the pattern of the antenna **105** in a planar view will be described later, with reference to FIGS. **4**A to **4**D.

The IC chip **106** is mounted on a surface of a base portion **110** and is electrically connected to the antenna **105**. The IC chip **106** is mounted on the surface of the sheet **103** with, for example, an underfill material.

Once the IC chip **106** receives a read signal of a radio frequency (RF) band from a reader/writer for the RFID tag **100** through the antenna **105**, the IC chip **106** is activated by electricity of the received signal, and transmits identification information through the antenna **105**. In response, the reader/writer reads the identification signal from the RFID tag **100**.

The package **102** includes a lower side portion **102**A and an upper side portion **102**B, which are arranged so as to cover the lower and upper sides, respectively, of the inlet **101** processed into a wave shape. Each of the lower side portion **102**A and the upper side portion **102**B is larger than the inlet **101** in a planar view. The respective parts of the lower side portion **102**A and the upper side portion **102**B which surround the inlet **101** are thermally fused so as to be joined together. In this manner, the package **102** entirely covers the inlet **101**.

The lower side portion **102**A of the package **102** may be subjected to pre-processing, through which part of the upper surface thereof, which is to be brought into contact with the sheet **103**, is formed in a wave shape in accordance with the wave shape of the sheet **103** and the lower surface thereof is formed to be flat. Alternatively, the lower side portion **102**A may be a flat rubber sheet, as long as the rubber sheet is elastic and flexible enough to absorb the projections and depressions of the wave shape of the sheet **103**. In this case, out of the flat rubber sheet used as the lower side portion **102**A, only part which makes contact with the sheet **103** includes a wave shape.

The lower surface of the lower side portion **102**A is to be affixed to an article which is identified with the RFID tag **100**. The package **102** includes end portions **102**E and **102**F arranged at either end in the longitudinal direction.

Likewise, the upper side portion **102**B of the package **102** may be subjected to pre-processing, through which part of the upper surface thereof, which is to be brought into contact with the sheet **104**, is formed in a wave shape in accordance with the wave shape of the sheet **104** and the lower surface thereof is formed to be flat. Alternatively, the upper side portion **102**B may be a flat rubber sheet, as long as the rubber sheet is elastic and flexible enough to absorb the projections and depressions of the wave shape of the sheet **104**. In this case, out of the flat rubber sheet used as the upper side portion **102**B, only part which makes contact with the sheet **104** includes a wave shape.

The package **102**, as described above, may be made of any given material having flexibility and elasticity. For example, the package **102** may be a member having entropic elasticity. The meaning of "entropic elasticity" includes, for example, rubber elasticity and elastomeric elasticity. Accordingly, a rubber material having rubber elasticity or an elastomeric material having elastomeric elasticity may be used.

Examples of the rubber material include, but are not limited to, a silicone (silica ketone) rubber, a butyl rubber, a nitryl rubber, a hydrogenation nitryl rubber, a fluorocarbon rubber, an epichlorohydrin rubber, an isoprene rubber, a chlorosulfonated polyethylene rubber, and a polyurethane rubber.

Examples of the elastomeric material include, but are not limited to, vinyl chloride, styrene, olefin, ester, urethane, and amidic elastomeric materials.

FIGS. **4**A to **4**D are views illustrating the inlet **101** of the RFID tag **100** according to the first embodiment. Specifically, FIG. **4**A is a view of the upper surface of the inlet **101**; FIG. **4**B is a cross-section view of the inlet **101**; FIG. **4**C is a view of the upper surface of the inlet **101** before it is processed into a wave shape; and FIG. **4**D is a cross-section view of the inlet **101** before it is processed into a wave shape. In more detail, FIG. **4**B is a cross section view taken along an arrow IVB-IVB of FIG. **4**A, and FIG. **4**D is a cross section view taken along an arrow IVD-IVD in FIG. **4**C.

As illustrated in FIGS. **4**A and **4**B, the inlet **101** includes the sheets **103** and **104**, the antenna **105**, and the IC chip **106**. The inlet **101** includes a middle portion **101**A located in the middle thereof in a longitudinal direction of the inlet **101** (or in an X-axial direction of FIG. **4**A), and the middle portion **101**A includes a flat shape, namely, is not processed into a wave shape, in order to allow the IC chip **106** to be mounted thereon.

The antenna **105** includes connection terminals **105**A and **105**B that are connected to the IC chip **106**, end portions **105**C and **105**D, and a connection portion **105**E.

The connection terminals **105**A and **105**B are not connected to each other, but are connected to corresponding terminals formed on the lower surface of the IC chip **106**. The IC chip **106** is mounted on the surface of the sheet **103** with, for example, an underfill material, so that the connection terminals **105**A and **105**B are connected to the terminals of the IC chip **106**.

Each of the end portions **105**C and **105**D includes a rectangular shape in a planar view. The end portions **105**C and **105**D are connected to the connection terminals **105**A and **105**B, respectively, by corresponding linear patterns.

One end of the connection portion **105**E is connected to a connection node **105**F between the connection terminal **105**A and the end portion **105**C, whereas the other end of the connection node **105**G is connected to a connection node **105**G between the connection terminal **105**B and the end portion **105**D. The connection portion **105**E is patterned in a U-shape between the connection nodes **105**F and **105**G.

The length of the antenna **105** may be set in accordance with a frequency to be used in wireless communication conducted by the RFID tag **100**. For example, since a frequency band of 952 MHz to 954 MHz or 2.45 GHz is assigned to a frequency for RFID tags in Japan, the length of the antenna **105** between the end portions **105**C and **105**D through the connection terminals **105**A and **105**B may be set to ½ of a wavelength λ, of the used frequency. Likewise, since frequency bands of 915 MHz and 868 MHz are assigned as typical frequencies in the USA and the EU, respectively, the length of the antenna **105** may be set to ½ of a wavelength λ, of either of these used frequencies. Note that the length of the antenna **105** may also be defined as that between the end portions **105**C and **105**D through the connection portion **105**E.

FIGS. **4**C and **4**D illustrate upper and side surfaces, respectively, of the inlet **101**, before it is processed into a wave shape. The inlet **101** illustrated in FIG. **4**C or **4**D is about 1.5 times as long as that illustrated in FIG. **4**A or **4**B, because the length of the inlet **101** is decreased by being processed into a wave shape. Note that a method of processing the inlet **101** into a wave shape will be described later.

Next, a description will be given of a state in which the RFID tag **100** is fastened to an article having a curved surface, with reference to FIGS. **5**A to **5**D.

FIGS. **5**A to **5**D are views illustrating a fastened state of the RFID tag **100** according to the first embodiment.

In this embodiment, as illustrated in FIG. **5**A, bands **110**A and **110**B are attached to both sides of the RFID tag **100** in a longitudinal direction of the RFID tag **100**. The bands **110**A and **110**B are provided with a hole IIIA and a button IIIB, respectively. By attaching or inserting the button IIIB to the hole IIIA, the bands **110**A and **110**B form a loop.

In FIGS. **5**B to **5**D, the RFID tag **100** is fastened to a cylindrical article **120** by the bands **110**A and **110**B, with the attached surface of the RFID tag **100** being in contact with the side surface of the cylindrical article **120**. Specifically, FIG. **5**B is a view of the upper surface of the RFID tag **100** fastened to the article **120**; FIG. **5**C is an enlarged perspective view of the RFID tag **100**; and FIG. **5**D is a side view thereof.

As illustrated in FIGS. **5**B to **5**D, when the RFID tag **100** is fastened to the curved side surface of the cylindrical article **120**, the inlet **101** is bent so as to fit the curved side surface. Thus, the damaging of the inlet **101** is suppressed. In this state, the PET sheets **103** and **104** are also bent so as to fit the curved side surface of the article **120**. Since the sheets **103** and **104** are processed into a wave shape, they are able to be bent and fit a curved surface more easily than sheets that are not processed into a wave shape.

Moreover, since the antenna **105** is made of an Ag paste, as described above, it is less prone to being damaged even when being bent in conjunction with the sheets **103** and **104**.

When the inlet **101** is bent in the above manner, the IC chip **106** slightly becomes separated from the side surface of the article **120** due to the projections and depressions of each wave shape of the sheets **103** and **104**. As a result, the stress transferred from the lower side portion **102**A of the package **102** to the IC chip **106** is decreased. For this reason, damaging of the connection portions of the antenna **105** and the IC chip **106** are suppressed.

The package **102** is made of rubber, as described above. Therefore, even when the inlet **101** is bent as illustrated in FIGS. **5**A to **5**D, the package **102** is not affected at all.

As described above, the inlet **101** including the sheets **103** and **104** is configured to be bent so as to fit the side surface of the cylindrical article **120**. Consequently, it is possible for the RFID tag **100** according to the first embodiment to be fastened to a curved surface without being damaged.

Next, a description will be given of a case where the RFID tag **100** is bent and formed into a circular shape by connecting both ends thereof disposed in the longitudinal direction, with reference to FIGS. **6**A to **6**C.

FIGS. **6**A to **6**C are views illustrating another fastened state of the RFID tag **100** according to the first embodiment. Specifically, FIG. **6**A is a view of the upper surface of the RFID tag **100** having a circular shape; FIG. **6**B is a view of the upper surface of the circular RFID tag **100** in a fastened state; and FIG. **6**C is a side view thereof.

As illustrated in FIG. **6**A, the RFID tag **100** is formed into a circular shape by connecting the end portions **102**E and **102**F which are arranged at either end of the RFID tag **100** in the longitudinal direction. The end portions **102**E and **102**F may be connected with an acrylic adhesive tape.

The RFID tag **100** that forms a circular shape in the above manner is fastened to the side surface of a cylindrical article **130**, as illustrated in FIGS. **6**B and **6**C.

When the RFID tag **100** is fastened to the side surface of the cylindrical article **130**, the sheets **103** and **104** of the inlet **101** in the RFID tag **100** are bent along the curved surface without being damaged, similar to the case illustrated in FIGS. **5**A to **5**D. Furthermore, neither of the antenna **105** and the IC chip **106** are damaged or affected. Likewise, the package **102**, made of rubber, is not affected at all even when being bent as illustrated in FIGS. **6**A to **6**C.

The inlet **101** including the sheets **103** and **104** is configured to be bent in the above manner. Therefore, it is possible for the RFID tag **100** according to the first embodiment to be fastened to the curved side surface of the cylindrical article **130** and fit the curved surface while being formed into a circular shape by connecting both ends of the RFID tag **100** which are arranged in the longitudinal direction.

As described above, the first embodiment may make it possible to provide a highly durable RFID tag.

In the above description, when the RFID tag **100** is fastened to a curved surface, such as the side surface of the cylindrical article **120** or **130**, the RFID tag **100** is bent into an arc or circular shape. Here, the articles **120** and **130** are not deformed, and therefore the dimensions and sizes of their side surfaces are fixed.

Meanwhile, when fastened to an elastic curved surface, the RFID tag **100** may expand or shrink in the longitudinal direction, in addition to being bent.

To give an example, it is assumed that an RFID tag which is not processed into a wave shape, such as that of the comparative example, is fastened to the curved surface of an elastic article. When the article expands or shrinks, the RFID tag may fail to absorb the deformation of the article which is caused by the expansion or shrinkage. In this case, the RFID tag is prone to being damaged.

To give another example, it is assumed that the RFID tag **100** according to the first embodiment is fastened to the curved surface of an elastic article. When the article expands or shrinks, the RFID tag **100** successfully absorbs the deformation caused by the expansion or shrinkage via deformation of the inlet **101** processed into a wave shape, as long as the expansion or shrinkage occurs in a longitudinal direction of the RFID tag **100**. Consequently, the first embodiment makes it possible to provide a highly durable RFID tag that is capable of being fastened to the curved surface of an elastic article.

The cause of the deformation, expansion or shrinkage of an article is considered to be surrounding heat, an external stress, or the like.

Next, a description will be given of a method of processing the inlet **101** into a wave shape, with reference to FIGS. **7**A to **7**G.

FIGS. **7**A to **7**G are views illustrating processing steps subjected to the inlet **101** of the RFID tag **100** according to the first embodiment. Specifically, FIGS. **7**A to **7**C and FIGS. **7**D to **7**G illustrate different processes. Note that in FIGS. **7**A to **7**G, the inlet **101** is illustrated simplistically.

At the step of FIG. **7**A in the process of FIGS. **7**A to **7**C, jigs **140**A and **140**B are used. The jig **140**A includes two wave portions **141**A and **141**A and a flat portion **142**A. The flat portion **142**A is located between the wave portions **141**A and **141**A. The jig **140**B includes wave portions **141**B and **141**B and a flat portion **142**B. The flat portion **142**B is located between the wave portions **141**B and **141**B.

The wave portions **141**A and **141**A of the jig **140**A includes the same wave phase as the wave portions **141**B and **141**B of the jig **140**B. When the jigs **140**A and **140**B are abutted against each other, the flat portions **142**A and **142**B are arranged to oppose each other while being separated by a distance defined by totaling the individual thicknesses of the sheets **103** and **104**, the antenna **105** and the IC chip **106**, and a predetermined margin.

The flat portion **142**A is located on the same level as the top of the wave portions **141**A and **141**A, and the flat portion **142**B is located on the same level as the top of the wave portions **141**B and **141**B.

As illustrated in FIG. **7**A, the inlet **101** is set between the jigs **140**A and **140**B. In more detail, the inlet **101** is set such that the IC chip **106** is located between the flat portions **142**A and **142**B and the sheets **103** and **104** (see FIG. **3**A) are arranged on the upper and lower sides, respectively. In this case, the jigs **140**A and **140**B are preheated at a predetermined temperature, such as 60° C.

Then, as illustrated in FIG. **7**B, the inlet **101** is sandwiched and pressed by the jigs **140**A and **140**B while the temperature of the jigs **140**A and **140**B is maintained. Through this step, the inlet **101** is subjected to thermal and pressurizing treatments at the same time. At the step of FIG. **7**B, the treatment time and pressure may be optimized in accordance with, for example, the individual thicknesses of the sheets **103** and **104** in the inlet **101**.

Finally, as illustrated in FIG. **7**C, the jigs **140**A and **140**B are separated, and then the inlet **101** that has been processed into a wave shape is taken out from the jigs **140**A and **140**B. Through the above steps, the fabrication of the wave-shaped inlet **101** is completed.

In FIG. **7**A, each of the flat portions **142**A and **142**B is located on the same level as the top of the corresponding wave shape, as described above. With the jigs **140**A and **140**B configured above, a sufficient distance is able to be secured between the article and the IC chip **106**, when a surface of the RFID tag **100** which is closer to the sheet **103** of the inlet **101** is affixed to an article. Consequently, a stress applied to the IC chip **106** which is generated when the RFID tag **100** is bent is decreased.

Alternatively, each of the flat portions **142**A and **142**B of the jigs **140**A and **140**B, respectively, may be located at the middle position of the top and bottom of the corresponding wave shape. In this case, a distance is able to be secured between the IC chip **106** and the upper surface of the inlet **101** (or the sheet **104**).

Moreover, each of the flat portions **142**A and **142**B may also be located on the same level as the bottom of the corresponding wave shape. In sum, the heights of the flat portions **142**A and **142**B may be set as appropriate in accordance with, for example, the application of the RFID tag **100**.

On the other hand, in the processing step of FIG. **7**D to **7**F, first, jigs **150**A and **150**B are used as illustrated in FIG. **7**D. Note that the jigs **150**A and **150**B are preheated.

The jig **150**A is provided with four projections **151**A, and is retained so as to be rotatable along the upper surface of the jig **150**B. The projections **151**A of the jig **150**A are formed so as to correspond to the shape of two wave portions **151**B of the jig **150**B.

The jig **150**B is provided with the wave portions **151**B and **151**B and a flat portion **152**B. The flat portion **152**B is located between the wave portions **151**B and **151**B preferably at a central region between the wave portions **151**B and **151**B.

As illustrated in FIG. **7**D, first, the inlet **101** is set on the jig **150**B, and the jig **150**A is rotated and moved from the left location of FIG. **7**D to a location illustrated in FIG. **7**E. In other words, the jig **150**A is rotated and moved to a location in front of the flat portion **152**B.

Then, the jig **150**A is temporarily lifted so as to become separated from the jig **150**B, and moved to the opposite end of the inlet **101** in a longitudinal direction of the inlet **101** (or on the right side of FIG. **7**F), as illustrated in FIG. **7**F. Followed by, the jig **150**A is rotated and moved from the opposite end to a location in front of the flat portion **152**B, so that the processing is subjected to a region from the opposite end to the front location.

Through the above steps, the inlet **101** is able to be processed into a wave shape, as illustrated in FIG. **7**G.

Next, a description will be given of a wave shape of the inlet **101**, and an allowable expansion and shrinkage rate of the inlet **101** in a longitudinal direction thereof, with reference to FIGS. **8** to **11**A and **11**B.

FIGS. **8**, **9**A and **9**B are explanatory views of a wave shape of the RFID tag **100** according to the first embodiment. In FIGS. **8**, **9**A and **9**B, the inlet **101** is simplistically illustrated as a wave, such as a sinusoidal wave.

Here, a wave shape of the inlet **101** is regarded as a wave formed by combining arcs and straight lines. Specifically, as illustrated in FIG. **8**, a wave representing a wave shape of the inlet **101** is formed by continuously connecting a straight line α and an arc β.

As illustrated in FIG. **8**, as to the wave representing the wave shape of the inlet **101**, the amplitude (height), period (pitch), and curvature radius, and peak angle are denoted by H, P, R and A, respectively.

Then, as illustrated in FIG. **9**A, when each straight line α contained in the wave is extended by a dotted line, adjacent dotted lines α make contact with each other at a point γ. In this case, a vertical distance L between the respective points γ located above and below the wave is expressed by an equation (1).

$$L=(P/2)/\tan(A/2) \tag{1}$$

FIG. **9**B is an enlarged view of part surrounded by a dotted line IXB of FIG. **9**A. In FIG. **9**B, a central point of the arc β is denoted by O, and an intersection point of a straight line which passes through the central point O and extends in a just downward direction and both the arc β and the straight line α is denoted by X. Furthermore, in FIG. **9**B, the point γ of FIG. **9**A is denoted by a point Y, and an intersection point of a straight line OY and the arc β is denoted by Z. When the peak angle A is used in addition to these parameters, lengths of the straight lines OY and ZY are expressed by equations (2) and (3), respectively. The equation (3) is given by changing the equation (2).

$$OY=R/\sin(A/2), OZ=R \tag{2}$$

$$ZY=OY-OZ=R/\sin(A/2)-R \tag{3}$$

Then, the height (amplitude) H of the wave shape is expressed by an equation (4).

$$\begin{aligned} H &= L-2\cdot ZY \\ &= (P/2)/\tan(A/2)-2\{R/\sin(A/2)-R\} \\ &= (P/2)\cdot\tan(A/2)-2\cdot R/\sin(A/2)+2R \end{aligned} \tag{4}$$

Accordingly, when the wave shape of the inlet **101** is designed, it is preferable for the height (amplitude) H of the wave shape to be set by using the equation (4).

Next, a description will be given of an expansion and shrinkage rate of the inlet **101**, with reference to FIGS. **10**A and **10**B and FIGS. **11**A and **11**B. The package **102** of the RFID tag **100** is more likely to be deformed than the inlet **101** is. Therefore, an expansion and shrinkage rate of the RFID tag **100** is deemed to be determined by an expansion and shrinkage rate of the inlet **101**.

FIGS. **10**A and **10**B are views illustrating the expansion and shrinkage of the inlet **101**. FIGS. **11**A and **11**B are explanatory views of a method of determining an expansion and shrinkage rate of the inlet **101**.

When no force is applied to the inlet **101** processed into a wave shape, the inlet **101** has a length, such as that illustrated in FIG. **10**A. Then, when the right end of the inlet **101** of FIG. **10**A is pulled in the right direction, the inlet **101** expands linearly as illustrated in FIG. **10**B. As is clearly understood from FIGS. **10**A and **10**B, the inlet **101** is expandable in a longitudinal direction thereof, and once a pulling force is released from the inlet **101** in a state of FIG. **10**B, the inlet **101** shrinks until it returns to be in a state of FIG. **10**A.

Here, an allowable expansion and shrinkage rate C of the inlet **101** is determined.

As illustrated in FIG. **11**A, points M and N are set. These points M and N correspond to the point γ of FIG. **9**A.

In FIG. **11**A, an equation (5) is satisfied.

$$MY\cdot\sin(A/2)=P/2 \tag{5}$$

By changing the equation (5), an equation (6) is given.

$$MY=(P/2)/\{\sin(A/2)\} \tag{6}$$

FIG. **11**B is an enlarged view of part surrounded by a dotted line XIB of FIG. **11**A.

In FIG. **11**B, an angle between straight lines OX and OY is $(\pi/2-A/2)$, and an angle between straight lines OY and XY is A/2.

Accordingly, equations (7) and (8) are satisfied.

$$XY\cdot\tan(A/2)=R \tag{7}$$

$$XY=R/\tan(A/2) \tag{8}$$

Here, since a length of an arc XZ is obtained by multiplying a radius of the arc XZ by a central angle thereof, it is determined by R(π/2−A/2).

As described above, a period S of the wave representing the wave shape of the inlet **101** is determined by an equation (9).

$$\begin{aligned} Q &= 2MY - 4XY + 4XZ \\ &= 2\cdot(P/2)/\{\sin(A/2)\} - 4\cdot R/\tan(A/2) + 4\cdot R(\pi/2 - A/2) \\ &= P/\sin(A/2) - 4\cdot R/\tan(A/2) + 2R(\pi - A) \end{aligned} \tag{9}$$

Accordingly, the expansion and shrinkage rate C of the inlet **101** is expressed by an equation (10).

$$C=\{P/\sin(A/2)-4R/\tan(A/2)+2R(\pi-A)\}/P-1 \tag{10}$$

As described above, when the RFID tag **100** according to the first embodiment is fastened to an elastic article, it is preferable for the RFID tag **100** to be designed in consideration of an expansion and shrinkage rate of the inlet **101** which is determined by the equation (10).

Note that the above description has been given, regarding the case where the RFID tag **100** includes a flat affixed surface (or a flat lower surface); however, the following modifications are also applicable, as illustrated in FIGS. **12**A and **12**B.

FIGS. **12**A and **12**B are views illustrating RFID tags **100**C and **100**D, respectively, according to modifications of the first embodiment.

As illustrated in FIG. **12**A, the lower surface of the RFID tag **100**C may be formed in a wave shape. Specifically, in the RFID tag **100**C, the lower side portion **102**A of the package **102** is formed in a wave shape. By forming the lower surface of the RFID tag **100**C in a wave shape, the RFID tag **100**C is able to be bent along a curved surface more easily.

Meanwhile, in the RFID tag **100**D of FIG. **12**B, the inlet **101** includes a different wave period from that of the upper side portion **102**B of the package **102**. Specifically, the wave period of the upper side portion **102** is twice as long as that of the inlet **101**. Thus, the inlet **101** and the upper side portion **102**B may include different wave periods; however it is preferable for both periods to be related to each other so as to satisfy an integral multiple relationship. By relating the periods of the inlet **101** and the upper side portion **102**B to each other, the RFID tag **100**D is able to be bent along a curved surface easily.

The above description has been given, regarding the case where the RFID tag **100** is processed into a wave shape. Further, the RFID tag **100** may be configured such that at least the sheets **103** and **104** are provided with projection-depression portions formed in a longitudinal direction thereof.

For example, the upper side portion **102**B of the package **102** may include a flat upper surface. Even in this case, the RFID tag **100** is able to be bent along a curved surface. This is because the package **102**, made of rubber, is bent more easily than the inlet **101** is.

The above description has been given, regarding the case where the inlet **101** is processed into a wave shape; however the shapes of the sheets **103** and **104** in the inlet **101** are not limited to a wave shape. There is no limitation on the shapes of the sheets **103** and **104** as long as they include projection-depression portions formed in a longitudinal direction thereof. For example, the sheet **103** may be a sheet-shaped PET film having a lower surface on which a plurality of projections are formed in a longitudinal direction thereof, and the sheet **104** may be a sheet-shaped PET film having an upper surface on which a plurality of projections are formed in a longitudinal direction thereof.

Even in this case, the sheets **103** and **104** are able to be bent along a curved surface more easily than a flat PET film is.

The above description has been given, regarding the case where the sheets **103** and **104** of the inlet **101** are processed into a wave shape. However, a configuration of the RFID tag **100** according to the first embodiment is not limited to that has been described above. Instead of the configuration in which the sheets **103** and **104** of the inlet **101** are processed into a wave shape, a configuration in which grooves are formed in the lower surface of the sheet **103** and the upper surface of the sheet **104** may be employed.

It is preferable for the grooves to be formed in the lower surface of the sheet **103** and the upper surface of the sheet **104** along a direction orthogonal to a longitudinal direction in a planar view (or along a Y-axial direction). Here, the direction orthogonal to the longitudinal direction in a planar view (or along the Y-axial direction) refers to a direction along the short side of the RFID tag **100**.

Forming the grooves in the above manner enable the sheets **103** and **104** to be bent in the longitudinal direction easily.

Alternatively, such grooves may be formed in a direction forming an angle with the longitudinal direction in a planar view. In other words, a direction along which grooves are formed is not limited to that orthogonal to the longitudinal direction in a planar view (or along the Y-axial direction).

The reason is that it is possible for the sheets **103** and **104** to be bent in the longitudinal direction easily even by forming the grooves in a direction forming an angle with the longitudinal direction in a planar view.

Second Embodiment

FIGS. **13**A and **13**B are views illustrating an RFID tag **200** according to the second embodiment. Specifically, FIG. **13**A is a cross-section view of the whole of the RFID tag **200**, and FIG. **13**B is an enlarged view of part surrounded by a dotted line XIIIB of FIG. **13**A. The cross-section of the RFID tag **200** in FIG. **13**A corresponds to that of the RFID tag **100** according to the first embodiment in FIG. **3**A. In FIGS. **13**A and **13**B, the dimensions of the RFID tag **200** are defined by an orthogonal coordinate system, more specifically, an XYZ coordinate system.

The RFID tag **200** according to the second embodiment includes an inlet **101** and a package **202**. The inlet **101** is the same as that of the first embodiment, and therefore a description thereof will be omitted. In the RFID tag **200**, the lower surface of the package **202** is to be affixed to an article.

The package **202** differs from the package **102** of the first embodiment, in that the upper surface thereof is provided with grooves **202**C formed so as to extend along a direction orthogonal to a longitudinal direction in a planar view (or along a Y-axial direction in FIG. **13**A), in place of the wave shape. Except for this difference, the package **202** includes the same structure as the package **102** of the first embodiment does. For this reason, the following description of the second embodiment is focused on the difference from the first embodiment. Here, the direction orthogonal to the longitudinal direction in a planar view (or along the Y-axial direction) refers to a direction along the short side of the RFID tag **200**.

The package **202** includes a lower side portion **202**A and an upper side portion **202**B. The lower side portion **202**A includes the same structure as the lower side portion **102**A of the first embodiment does.

The upper surface of the upper side portion **202**B is provided with a plurality of grooves **202**C formed along the short side. The grooves **202**C are formed at locations where the upper surface of the sheet **104** in the inlet **101** is depressed. Specifically, the locations at which the grooves **202**C are formed correspond to a wave period of the inlet **101**. The grooves **202**C are an example of a third groove portion.

The grooves **202**C, as described above, may be formed by subjecting the upper surface of the upper side portion **202**B to, for example, machine processing using a cutter and the like or irradiation processing using a laser.

The lower side portion **202**A and the upper side portion **202**B are arranged covering the lower and upper surfaces, respectively, of the inlet **101** which are processed into a wave shape. Each of the lower side portion **202**A and the upper side portion **202**B is larger than the inlet **101** in a planar view. The lower side portion **202**A and the upper side portion **202**B are joined together through the respective parts which surround the inlet **101** by, for example, being thermally fused. As a result, the package **202** entirely covers the inlet **101**.

When the RFID tag **200**, as described above, according to the second embodiment is fastened to, for example, the side surface of a cylindrical article, it is bent along the curved surface, similar to the RFID tag **100** according to the first embodiment. This is because the grooves **202**C which are formed on the upper surface of the upper side portion **202**B in the package **202** helps the upper side portion **202**B be bent in the longitudinal direction.

Consequently, the second embodiment makes it possible to provide a highly durable RFID tag, similar to the first embodiment.

Moreover, it is assumed that the RFID tag **200** according to the second embodiment is fastened to the curved surface of an elastic article. When this article expands or shrinks, the inlet **101** processed into a wave shape absorbs the expansion or shrinkage by being deformed as long as the expansion or shrinkage occurs in the longitudinal direction, similar to the RFID tag **100** according to the first embodiment. In this case, the upper side portion **202**B of the package **202** absorbs the expansion or shrinkage in conjunction with the inlet **101** by increasing or decreasing the widths of the grooves **202**C in the longitudinal direction.

Consequently, the second embodiment also makes it possible to provide a highly durable RFID tag that is capable of being fastened to the curved surface of an elastic article.

Note that the above description has been given, regarding the case where the RFID tag **200** includes a flat affixed surface (or a flat lower surface); however the following modifications are also applicable, as illustrated in FIGS. **14**A and **14**B.

FIGS. **14**A and **14**B are views illustrating RFID tags **200**A and **200**B, respectively, according to modifications of the second embodiment.

As illustrated in FIG. **14**A, the RFID tag **200**A may include a lower surface on which a plurality of grooves **202**D are formed. In other words, in the RFID tag **200**A, the grooves **202**D are formed on the lower surface of the lower side portion **202**A in the package **202**. Forming the grooves **202**D in the lower surface of the RFID tag **200** further helps the RFID tag **200** be bent along a curved surface.

On the other hand, in the RFID tag **200**B illustrated in FIG. **14**B, a wave period of the inlet **101** differs from a forming period of the grooves **202**C in the upper side portion **202**B of the package **202**. In more detail, the forming period of the grooves **202**C in the upper side portion **202** is twice as long as the wave period of the inlet **101**. Thus, the wave period of the inlet **101** may differ from the forming period of the grooves **202**C in the upper side portion **202**B; however it is preferable for the wave period and the forming period to be related to each other so as to satisfy an integral multiple relationship. By relating the wave period of the inlet **101** and the forming period of the grooves **202**C in the upper side portion **202**B, the RFID tag **200**B is able to be bent along a curved surface more easily.

The above description has been given, regarding the case where the grooves **202**C are formed in a direction orthogonal to the longitudinal direction in a planar view (or along the Y-axial direction). However, the groove **202**C may also be formed in a direction forming an angle with the longitudinal direction in a planar view. In other words, a direction along which grooves are formed is not limited to that orthogonal to the longitudinal direction in a planar view (or along the Y-axial direction).

The reason is that it is possible for the package **202** to be bent in the longitudinal direction easily even by forming the grooves **202**C in a direction forming an angle with the longitudinal direction in a planar view.

Up to this point, the RFID tags according to the embodiments have been described. However, the descriptions are not limited to those that have been concretely disclosed, and various modifications and variations thereof are applicable without departing from the scope of the claims.

All examples and conditional language recited herein are intended for pedagogical purposes to aid the reader in understanding the invention and the concepts contributed by the inventor to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions, nor does the organization of such examples in the specification relate to a showing of the superiority and inferiority of the invention. Although the embodiments of the present invention have been described in detail, it should be understood that the various changes, substitutions, and alterations could be made hereto without departing from the spirit and scope of the invention.

What is claimed is:

1. An RFID tag comprising:

a first sheet portion including a first projection-depression portion formed in a longitudinal direction or a first groove portion formed in a direction forming an angle with the longitudinal direction, the first projection-depression portion being provided to an upper and lower surfaces of the first sheet portion,

an antenna formed on a surface of the first sheet portion, the antenna being flexible and elastic;

an integrated circuit chip electrically connected to the antenna;

a second sheet portion including a second projection-depression portion formed in the longitudinal direction or a second groove portion formed in a direction forming an angle with the longitudinal direction, the second projection-depression portion being provided to an upper and rear surfaces of the second sheet portion, the antenna and the integrated circuit chip being covered between the first sheet portion and the second sheet portion, and

a package member covering the first sheet portion and the second sheet portion, the package member being flexible and elastic.

2. The RFID tag according to claim **1**, wherein

a phase of the first projection-depression portion or the first groove portion corresponds to a phase of the second projection-depression portion or the second groove portion.

3. The RFID tag according to claim **1**, wherein

the first projection-depression portion or the second projection-depression portion is at least part of the first sheet portion or the second sheet portion which is bent in a wave shape.

4. The RFID tag according to claim **1**, wherein

the first sheet portion includes a flat portion at a location corresponding to the IC chip.

5. The RFID tag according to claim **1**, wherein

the package member includes a third projection-depression portion or a third groove portion on a first outer surface portion or a second outer surface portion, the third projection-depression portion being formed in the longitudinal direction, the third groove portion being formed in a direction forming an angle with the longitudinal direction, the first outer surface portion being a side of the package member which covers the first sheet portion, the second outer surface portion being a side of the package member which covers the second sheet portion.

6. The RFID tag according to claim **5**, wherein

the package member includes the third projection-depression portion or the third groove portion on both the first outer surface portion and the second outer surface portion.

7. The RFID tag according to claim **5**, wherein

a phase of the third projection-depression portion or the third groove portion corresponds to a phase of the first projection-depression portion or the second projection-depression portion, or a phase of the first groove portion or the second groove portion.

8. The RFID tag according to claim **5**, wherein

the third projection-depression portion is at least part of the package member which is bent in a wave shape.

9. An RFID tag comprising:

a first sheet portion including a first projection-depression portion formed in a longitudinal direction or a first groove portion formed in a direction forming an angle with the longitudinal direction, the first projection-depression portion being provided to upper and lower surfaces of the first sheet portion;

an antenna formed on a surface of the first sheet portion, the antenna being flexible, elastic, and plate;

an integrated circuit chip electrically connected to the antenna;

a second sheet portion including a second projection-depression portion formed in the longitudinal direction or a second groove portion formed in a direction forming an angle with the longitudinal direction, the second projection-depression portion being provided to an upper and rear surfaces of the second sheet portion, the antenna and the integrated circuit chip being covered between the first sheet portion and the second sheet portion, and

a package member covering the first sheet portion and the second sheet portion, the package member being flexible and elastic.

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